Object-Oriented Design of a Dynamic Planner for Air Traffic Control Real-Time Sequencer, Scheduler, and Runway Allocator

Gregory L. Wong, Harry N. Swenson

The Dynamic Planner (DP) was designed, implemented, and integrated into the Center/TRACON (Terminal Radar Approach Control) Automation System (CTAS) to assist Traffic Management Coordinators (TMCs) in their task of planning and scheduling arrival traffic when that traffic is approximately 35 to 200 nautical miles from the destination airport. The TMC may input to the DP a series of current and future scheduling constraints that reflect the operational and environmental conditions of the airspace. Under these constraints, the DP uses flight plans, track updates, and estimated-time-of-arrival (ETA) predictions to calculate favorable runway assignments and arrival schedules that ensure a smooth flow of traffic into the terminal area. These runway assignments and schedules can be shown directly to controllers or they can be used by other CTAS tools to generate advisories to the controllers. Additionally, the TMC may override some of the decisions made by the DP and manually enter schedules, runway assignments, and sequences as the TMC sees fit. The DP will adapt its computations to accommodate these manual inputs. Should the TMC opt for a new plan, the constraints to the DP may be changed, and the DP will compute new runway assignments and schedules in real time.

In designing the DP, an object-oriented approach was used. Object-oriented design techniques were selected because of the ease with which the implementation task could be divided among the programming resources, as well as the ease with which the design could be maintained. Since the DP's operational deployment in 1996, a number of changes and new functionalities have been requested by air traffic controllers and researchers. The object-oriented approach to the DP's design and implementation made it possible for software engineers to readily modify the DP in response to these requests. This has resulted in short turnaround times and in rapid deployment of the new functionalities for evaluation in the field. As a result, the DP continues to evolve to meet the needs of air traffic controllers, TMCs, and researchers.

The Object Modeling Technique (OMT) object-oriented design method, developed by Rumbaugh (General Electric Research and Development Center, Schenectady, New York) and others, was used. The figure shows the high-level object model of the DP. Note that the Traffic Management Advisor (TMA) components external to the DP are shown as objects in the diagram. These external components are the Communications Manager (CM), Route Analyzer (RA), Timeline Graphical User Interface (TGUI), and a set of site-adapted data files known collectively as Site Dependencies.

The DP sequences and schedules arrival aircraft to the outer meter fix, meter fix, and runway in such a way as to maximize airport and TRACON capacity without compromising safety. Note that a blocked slot is a fake aircraft synthesized by a TMC to hold a place for a real aircraft which has not been entered into the system. Aircraft and blocked slots are collectively referred to as Schedulable Objects (SOs).

The DP's Sequence object puts the SOs into a first-come-first-served (FCFS) order at the meter fix. This is the order that TMCs are most comfortable with. However, a TMC may alter this order by manually entering one or more Sequence Constraints using the TGUI. The Sequence object will take these Sequence Constraints into account when setting the SO order.

The DP's Schedule object takes the order generated by the Sequence object and computes the scheduled time of arrival (STA) for each SO such that all Scheduling Constraints are satisfied. Scheduling Constraints are entered by the TMC using the TGUI. Scheduling Constraints reflect the landing rate at the airport, as well as the desired spacing between the aircraft near the meter fix and while landing. Furthermore, Scheduling Constraints may indicate that no aircraft may be scheduled to land during an interval of time set by the TMC. In addition to the Scheduling Constraints, the Schedule object takes into account the ETA of each SO as provided by the RA. The ETA represents the earliest possible time that an SO could arrive at a point if there were no other traffic in the

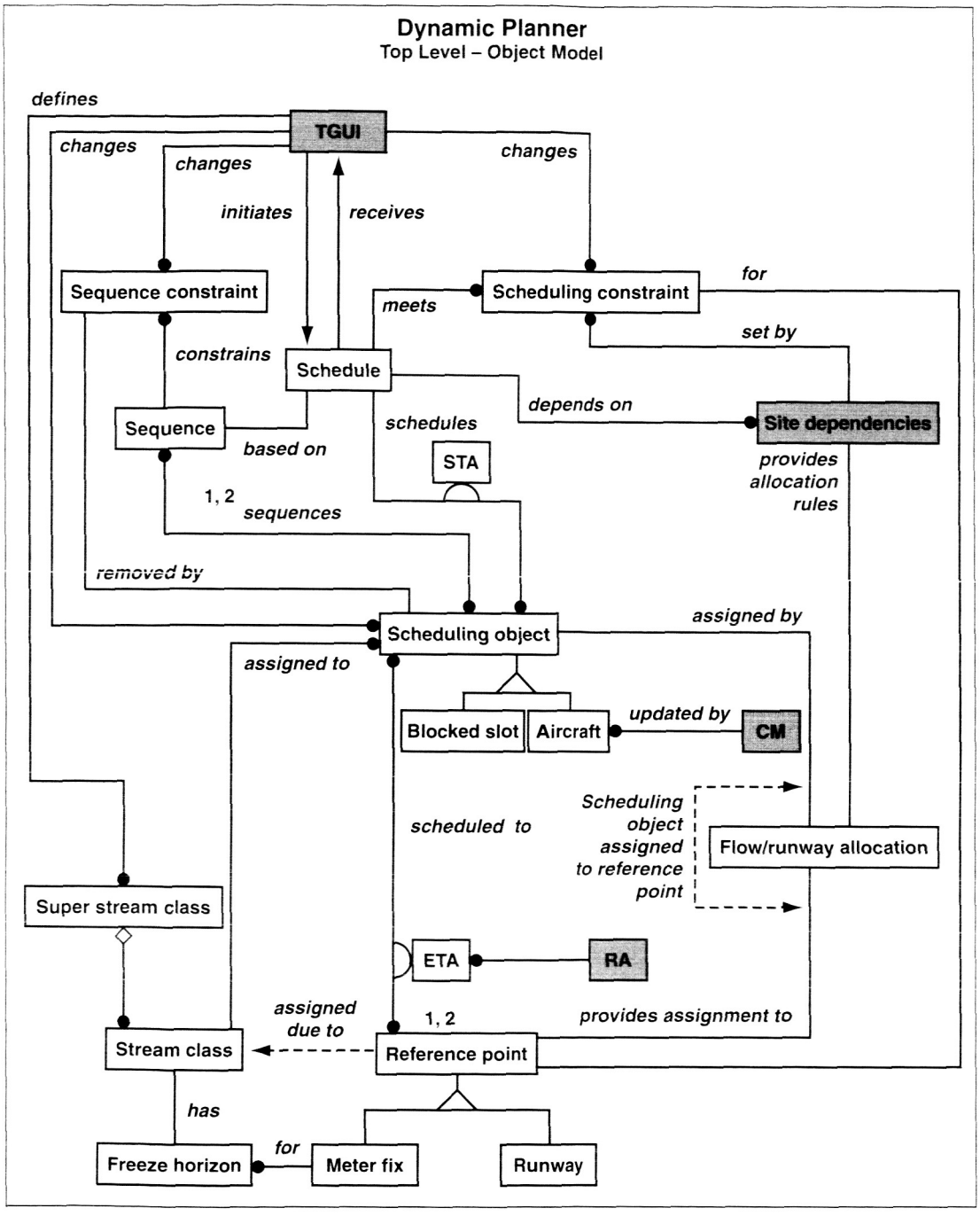

Fig. 1. Object model of the Dynamic Planner.

system. Thus, the STA of an SO computed by the Schedule object will not be earlier than the ETA of the SO.

In order to optimize the schedule that it computes, the DP will allocate SOs to the allowable runways using its Flow/Runway Allocation object. For each SO, the Flow/Runway Allocation object will assign the SO to each allowable runway and compute a set of STAs for all SOs as a result of that runway assignment. The runway assignment that minimizes the overall delay of all SOs is selected.

The scheduling and runway allocation processes are repeated periodically by the DP to ensure that the

STAs take into account the most recent traffic situation. This periodic update approximately corresponds to the rate at which aircraft-track updates are received. In addition, manual inputs by the TMCs, such as scheduling constraints, sequence constraints, and changes in the airport configuration, will trigger the DP to compute a new set of STAs and runway assignments to accommodate these changes.

The DP, as part of the TMA, has been in daily operational use throughout 1997 at the Traffic Management Unit at the Fort Worth Air Route Traffic Control Center. Feedback from TMCs, air traffic controllers, and researchers has defined new requirements that were unknown during the initial analysis and design phase. Because of the object-oriented design approach, however, these changes were quickly incorporated into the DP without disrupting its daily use.

Point of Contact: G. Wong/H. Swenson
(650) 604-1439/5469
glwong@mail.arc.nasa.gov
hswenson@mail.arc.nasa.gov

Daily Use of the Traffic Management Advisor

Harry N. Swenson, Shawn Engelland, Ty Hoang

The growth of commercial air travel and the "hub-and-spoke" operations used by many air carriers have put a severe strain on the Nation's air traffic capacity. This strain is safely, but many times inefficiently, absorbed by routine airborne and ground delays of aircraft. These delays cost the traveling public several billion dollars per year. The Center/TRACON (Terminal Radar Approach Control) Automation System (CTAS) is a joint NASA/Federal Aviation Administration (FAA) program that has as its goal the development of decision-support automation tools to efficiently reduce delays while maintaining a safe and reasonable level of controller workload.

The Traffic Management Advisor (TMA), developed under the CTAS program, is a time-based strategic planning and tactical advisory tool for traffic management coordinators and en route air traffic controllers. The TMA assists these air traffic control (ATC) specialists in efficiently and safely optimizing the capacity of a demand-impacted airport. The TMA software consists of highly accurate trajectory prediction, safety and ATC constraint-based scheduling with fuel-efficient delay distribution, traffic flow visualization, and controller advisories.

The TMA was installed and evaluated during a limited operational assessment in the summer of 1996 at the Fort Worth Air Route Traffic Control Center (ARTCC) and the Dallas/Fort Worth (DFW) Terminal Radar Control Facility, two of the busiest ATC facilities in the world. The benefits demonstrated during the assessment indicated that routinely the TMA saves 2 minutes of delay for every aircraft and, because of its efficient delay distribution scheduling, the routine landing capacity of the DFW TRACON was increased by 5%.

Following the success shown by the initial assessments, the FAA requested that NASA maintain the TMA on a daily use status throughout 1997. The figure shows the TMA as installed in the Traffic Management Unit at the Fort Worth ARTCC. The objective of this research was to expose the TMA to the broad spectrum of ATC personnel, as well as to

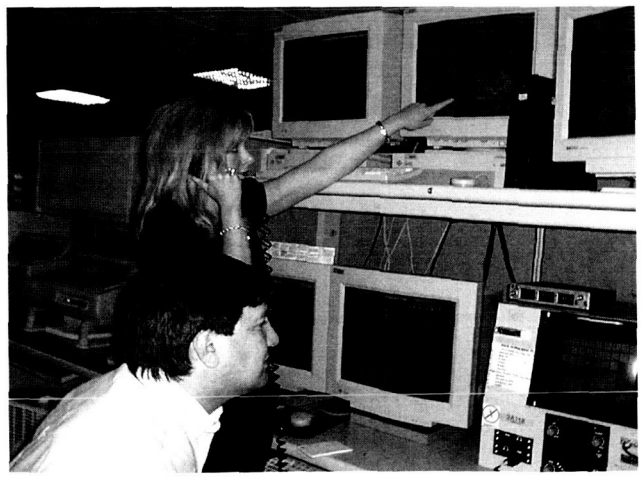

Fig. 1. Traffic Management Advisor installation at Fort Worth ARTCC.